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Ultrasound imaging has become a valuable adjunct for imaging of the breast, espescially in younger women with dense breasts. If the capability to reliably detect microcalcifications with conventional ultrasound equipment did exist, the sensitivity and specificity of ultrasound imaging for the detection of early breast cancer would increase dramatically
A new approach recently developed at the University of Missouri-Columbia has the potential to render microcalcifications detectable by a standard ultrasound scanner. The primary objective of the project is to prove that this approach has potential to detect microcalcifications in dense breast tissue. The initial task undertaken was to perform computer simulations of the scattering problem using models of the ultrasound beams and scattering from microcalcifications. Verification of the scattering simulation is underway using phantoms. The final goal of the project will be to obtain breast cancer specimens from clinical cases. These specimens will be imaged with a clinical mammography system to locate microcalcifications embedded within. Then the specimens will be imaged in the laboratory ultrasound system using the new technique.

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Introduction

This project was initiated to determine if a previously untried ultrasound technique might be capable of more readily identifying microcalcifications located in breast tissue. The project is defined in three components – a) computer simulation, b) phantom testing and c) testing on excised breast cancer samples.

Note: Because of delays in the issuance of the contract, this project did not begin until February 1, 2001. A final report will be submitted at the conclusion of this project.

Body

Component a) Computer simulations:

This phase of the project involved the work of at least three individuals in the project group. This computer simulation was performed using the following tools: MATLAB[1] and Field II[2]. *Field* is a set of MATLAB routines that perform a spatial impulse response calculation. The ultrasound field that exists at a specific point in space is represented as a function of time for when the ultrasound transducer is excited by a Dirac delta function. The field for a particular kind of excitation, for example, a sinusoidal function, may be determined by convolving that spatial impulse response with the excitation function. The sound reflected by a particular point scatterer in the field may be determined by a reciprocity relationship with the transducer, which is converted into a receiver in the second half of the ultrasound imaging experiment. The response of the transducer may be taken into account in the *Field* routines by incorporating the frequency response function. By following a linear systems theory, the voltage generated at the transducer by the excitation and the resultant echoes from the field can be determined[3-6]. *Field* takes into account the geometry and the response of the transducer.

(A description of the manipulation of the ultrasonic field will be included in the final version of this report.)

The computer simulations began with using *MATLAB* to create simulated breast tissue with spatially randomly distributed scatterers with uniform response within a volume. The echo signal generated by a relatively simple transducer was simulated using *Field*. A similar simulation was performed using a single scatterer representing a microcalcification, absent any other scatterers that would normally be found in the tissue volume. A final simulation of breast tissue included the single scatterer and the spatially randomly distributed scatterers that give rise to the speckle appearance of ultrasound images.

In the figure 1, the surface is a representation of the scattered ultrasound energy for an interaction of the ultrasound beam with a volume of diffuse scatterers. The are approximately 10 scatterers per mm^3 within this volume. The position of the transducer with respect to the scatterers is varied along one axis and the second axis is the frequency of the beam. The center frequency is 5 MHz for this piston shaped, flat faced transducer. Attenuation is modeled in the simulation to approximate that of soft tissue in the body (0.5 dB cm^{-1} MHz^{-1}).

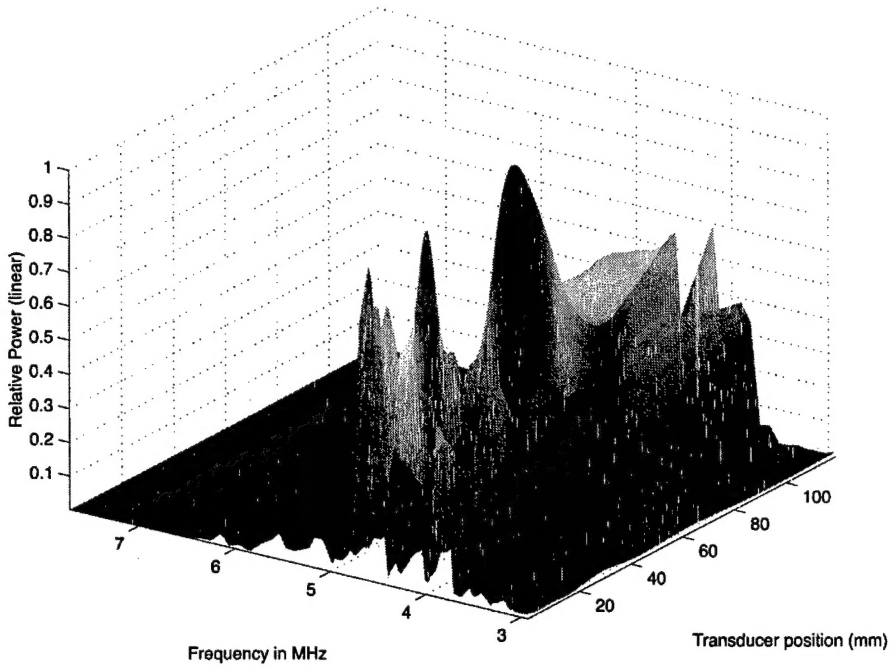

Figure 1

The interference of the beam, particularly in the complex near field of the transducer, results in a considerable amount of acoustic energy being spread out over frequencies away from the center of the spectrum.

In figure 2, the scattering field is that of a single, highly scattering object located within a volume. This would be representative of a single microcalcification in the absence of any other diffuse scatterers. All of the other conditions are identical to figure 1.

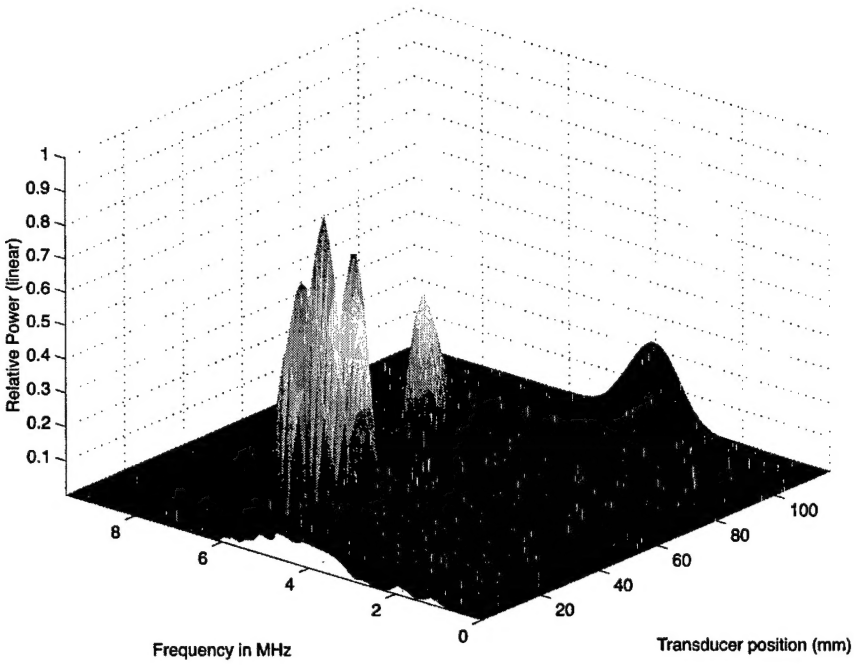

Figure 2

In figure 3 is depicted the result when the simulation is run with the simulated microcalcification embedded within the volume of diffuse scatterers. The scatterering amplitude of the microcalcification is approximately 80 times the scattering amplitude of the background (or diffuse) scatterers(or 19 dB per scatterer). This is closer to the clinical situation that would be encountered when an experiment is attempting to find a microcalcification.

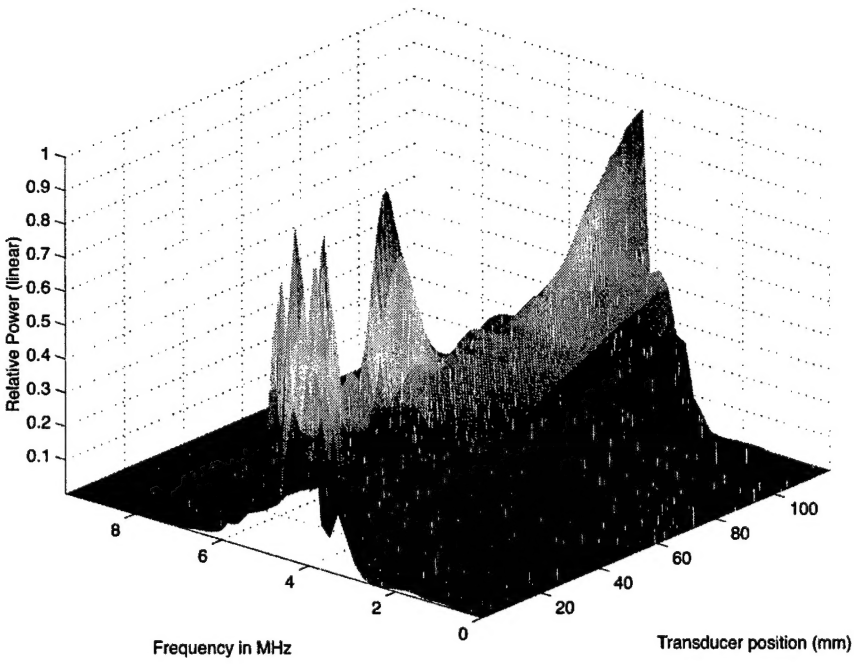

Figure 3

Note: Figure 3 depicts not a simple summation of the single point scatterer simulation with the 'diffuse only' simulation. It is a different simulation. The result is that the point (microcalcification) plot will have distinct patterns when compared to the case for the single scatterers. The detectable threshold of the simulation may well depend upon the size and shape, and therefore, the scattering level of the microcalcification(s). Additionally, the density and type of diffuse scatterers will be important. These will be clarified as we move into the phase of the work. Figure 4 shows the importance of this. In this, the ultrasound transducer conditions are identical to that of the previous figures, however, the scattering has changed to having 5 diffuse scatterers per mm3 and the scattering amplitude of the "microcalcification" is 16 dB above that of the diffuse scatterers. Figure 4a is the diffuse scattering volume only, figure 4b is the diffuse scatterers plus the "microcalcification".

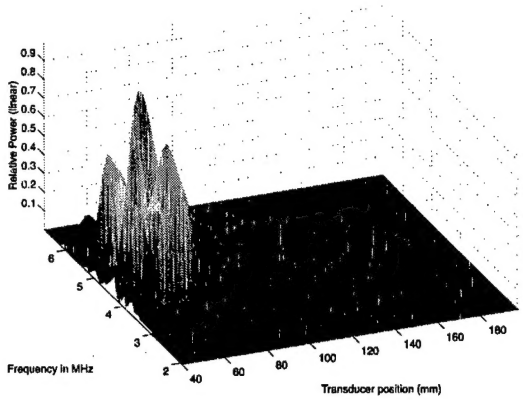

Figure 4a

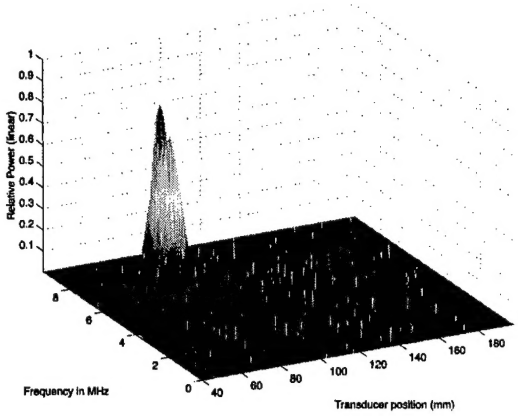

Figure 4b

The *Field* simulation software has a limitation in that it assumes that the scattering from a spherical object is uniform over all frequencies. This is known to be a simplification of the scattering problem. Work is ongoing to incorporate the models of Faran[7] into the simulation model.

Component b) Phantom testing:

Initial testing will be done using a derivation of a phantom with simulated microcalcifications of varying sizes for mammographic image evaluation. A phantom has been secured based upon the Gammex/RMI Model 156 mammographic phantom.

Component c) Evaluations on excised breast cancer tissue samples: This phase of the work has not yet begun.

Key Research Accomplishments (as of October 2001)

- simulations of the scattering problem using a accurate model of a pieozoelectric transducer
- incorporation of the Faran model for spherical scatterers into the simulations (ongoing)
- testing using a mammographic phantom (ongoing)
- evaluation using excised breast cancer tissue samples (not yet begun)

Reportable Outcomes – none at this time

Conclusions

Conclusions will be summarized in the final report. Initial results appear promising. However, more specific simulations and experiments are needed to verify.

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